Design of a Modular Motorcycle Windshield Wiper

By

Robert Allen Michael Boyd

SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2010

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Abstract

Motorcycle windshield wipers are essentially non-existent in the United States. Customer and market research reveals a demand for such a product. This paper explores the product viability of a modular motorcycle windshield wiper. The design and manufacturing of an alpha prototype, customer and market research, material selection, appropriate form, and prototype testing are all documented. The design of the alpha prototype utilizes two switches and a flip-flop circuit coupled with an h-bridge to achieve the desired oscillatory wiper motion. Throughout the design size, power, form, and manufacturing are taken into consideration. The objective of the paper is to lay the groundwork for a successful product innovation.

Thesis supervisor: David Wallace

Title: Professor of Mechanical Engineering

Design of a Modular Windshield Wiper for a Motorcycle

Author
Robert Allen Michael Boyd

Thank you!

David Walllace for giving me the opportunity to make this product. As an advisor you gave guidance whenever needed. Your course material from your product design classes has been an invaluable resource throughout the thesis work.

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John Williams for being a great thesis teammate. You and I have spent many nights working side-by-side on our theses.

Dodd Gray
Gavin Lund

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I. Introduction

A Motorcycle Windshield Wiper: But Why?

Meet Steve. Steve is a motorcycle enthusiast, and devoted rider. He owns a touring motorcycle and enjoys making motorcycle trips. Each year, Steve, along with over five hundred thousand motorcycle enthusiasts, gathers in Sturgis South Dakota for the largest motorcycle rally in the world (see Figure 1).

Figure 1: Motorcycles at Sturgis Motorcycle Rally in 2007

Steve takes pride in making the journey from California to Sturgis on his motorcycle. For Steve, the trip provides unique and scenic riding experience; it also gives him something to brag about to his biker friends. Riding a motorcycle lets him experience the environment, but it can also put him in dangerous riding conditions. While warm and sunny riding conditions are ideal, he sometimes has to ride through rain, hail, and even snow on the trip. One major complaint Steve has about riding in the rain is that his visibility greatly decreases. Although he enjoys the thrill of riding a motorcycle, Steve, like many riders, is greatly concerned with his own safety and wellbeing. His motorcycle has a windshield to block wind and debris. Even with the windshield, Steve says that sometimes, "I can't see a thing." Steve looked into a hand-operated wiper, but refuses to use it because he feels it would take too much attention from controlling the motorcycle. Part of the reason why Steve took so strongly to riding was for the image of being a "biker". Steve wants a windshield wiper for his motorcycle that he can take off when the weather is nice, or when he wants his "bike to look good." This concern is not surprising, as bikers tend to be an image conscious group (see Figure 2).

Figure 2: Bikers looking cool

Motorcycles are dangerous.

Approximately 80 percent of reported motorcycle crashes result in injury or death; for automobiles it is about 20 percent. An automobile has more weight and bulk than a motorcycle. It has door beams and a roof to provide some measure of protection from impact or rollover. It has cushioning and airbags to soften impact and safety belts to hold passengers in their seats. It has windshield washers and wipers to assist visibility in the rain and snow. An automobile has more stability because it's on four wheels, and because of its size, it is easier to see. A motorcycle pales in comparison when considering vehicle characteristics that affect safety.

Riding a motorcycle in the rain can be a dangerous encounter for even the most experienced riders. In the rain, other motorists, oil slicks, puddles of water, and even painted road lines are hazards for motorcycles. Rain can decrease visibility for the rider and other motorists, as well as make the rider less visible to other motorists. Even in ideal conditions, motorcycles are far less visible than automobiles; for this reason many modern motorcycle headlights do not have the ability to turn off if the engine is on. Loss of traction poses a great threat when riding in the rain. Once rain begins, particularly after an extended dry period, traffic oil in the road will wash up and make the road especially slippery. Motorcycles must avoid many hazards when riding in the rain. Maintaining vision is principal factor in remaining safe when riding in these conditions.

Use case

The wiper proposed is targeted towards long distance riders with touring motorcycles. A touring motorcycle is designed for long-distance riding and has features to address the needs of the rider. It is characteristic for these motorcycles to have large windshields, ample built-in storage, and twelve-volt power outlets for powering devices.

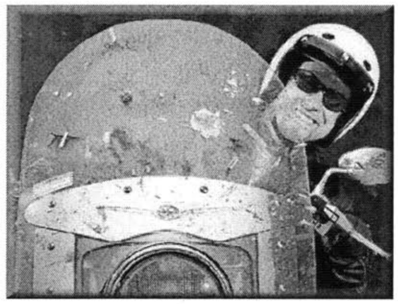


Figure 3: Exemplary windshield with low visibility

The wiper proposed is to be attached and used temporarily, if precipitation is encountered on a touring motorcycle. When precipitation is encountered the user would pull to the side of the road attach the wiper unit and simply plug it into the cigarette lighter power outlet to turn it on. Figure 3 shows a rider with low visibility. The wiper unit is compact and can easily be stored when is not in use. The alpha prototype is shown in Figure 4.

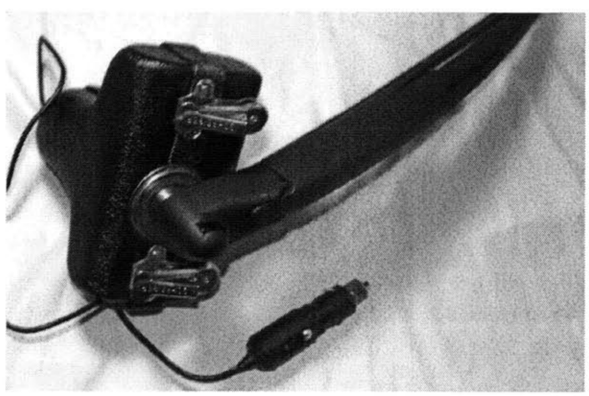


Figure 4: Prototype Wiper

Defining the goal

This paper explores the product viability of a modular motorcycle windshield wiper. Doing this includes the design and manufacturing of an alpha prototype, gathering customer and market research, material selection, finding an appropriate form, and prototype testing.

II. Market Research

Do people want one?

The idea for motorcycle windshield wiper is not a new one. Market research shows much interest among riders about wiping systems for motorcycles, but few examples in the US marketplace. The Japanese version of the Honda Goldwing, a large touring motorcycle, comes equip with built in windshield wiper. Due to severe traffic conditions in Japan, riding speeds are often slow enough that rain does not get blown off of the windshield. Japan also has a considerable rainy season. Honda sells motorcycles with wiper assemblies exclusively in Japan. Honda was contacted regarding their motorcycle wiper assembly, and was unable to supply the wiper parts or details outside of Japan.

After interviewing ten different motorcycle riders who had windshields installed, the over all consensus was that a windshield wiper would be useful when riding in the rain but about half felt that it would not be a worthwhile investment. Riders that went on long motorcycle rides saw more utility in owning a windshield wiper. In almost every case, riders felt that a wiper would aesthetically detract from their motorcycle.

The target users of this product are riders who own a touring motorcycle. Long-distance riders will get the most utility from a windshield wiper attachment. When it is raining, many motorcycle owners will use an alternate form of transportation. Riders on long trips do not have the luxury to do so. Touring motorcycles have large storage space in which the wiper could be stored, large windshields, and 12V cigarette power outlets. Of the 74,670 motorcycles sold by Harley-Davidson in 2008, 34% were touring motorcycles. Although not all were purchased for long distance riding, according to (2008 Harley-Davidson) 26,000 touring motorcycles is a sample market size. This product is ultimately intended for riders who have a motorcycle equip with a windshield and 12V power outlet. Market research indicates that a motorcycle windshield is a viable product option.

Benchmarking

When setting out to design the wiper, a few similar products were found. Le Wipe is a simple hand operated wiper produced by an individual and sold for $29.95 (2004 Le Wipe). It is a u-shaped wiper that rests atop the windshield. It wipes both sides of the windshield, using the left hand to push it across the top of the windshield. This model includes a coiled tether cord to prevent loss while riding. The product targets long distance riders, and was design by a rider who claims to ride over twenty thousand miles a year.

While researching similar products, a patent for a motorized windshield wiper was found. The patent says that the unit is easy to install. The unit is installed by drilling holes through the windshield for mounting rods and a motor shaft. Drilling holes near the base and attachment points can compromise the structural integrity of a windshield. It was discovered that this product is called Peer Clear, but the website was no longer active. Further research into the company indicates that the company no longer exists, but was sold for $329 as recently as 2007.

The Japanese Honda Goldwing is another example of a similar product. Due to its unavailability in the United States, information about it is unavailable.

A search for similar products shows that it is possible to add a motorized wiper to a motorcycle, but very few competitive products exist. It would seem that motorcycle windshield wipers is an unrealized market in the United States. Data collected is presented in Table 1.

Table 1: Chart benchmarking similar products

Product	Cost	Automated	Modular
Le Wipe	$30	No	Yes
Peer Clear	$329	Yes	No
Japanese Goldwing	N/A	Yes	No

Cost

The total cost of materials used in the prototype is given in Table 2.

Table 2: Bill of materials in prototype

Part	Count	Cost
DC Gear Motor	1	$ 91.33
Bearing	1	$ 29.30
Clamp	2	$ 10.66
Switch	2	$ 1.50
Wiper arm	1	$ 39.95
12" Al Hex Rod	1	$ 10.34
12" x 12" Al sheet	1	$ 21.27
12 VDC plug	1	$ 9.34
Polyethylene for Thermoformed Shell	1	$ 21.46
Electronics	N/A	< $2.00
Total		$ 239.21

III. Motorcycle Windshields

Plastics

Automobile windshields are typically made from a two layers of glass laminated over a layer of plastic. Because of the glass, car windshields are tough and abrasive resistant. Motorcycle windshields, on the other hand, are characteristically much softer. Motorcycle windshields are made from polycarbonate (Lexan), hard-coated polycarbonate, acrylic (Plexiglass), or Impact Modified Acrylic (2010 Allaboutbikes.com). Some states require for vehicles to adhere to standards set for the by the Department of Transportation (DOT), but windshield regulations are rarely enforced.

Some custom windshields do not conform to DOT standards. Polycarbonate, hard-coated polycarbonate, and Impact Modified Acrylic are all DOT approved materials for windshields; ordinary acrylic is not because, when fractured, it can shatter into sharp shards of plastic. Normal polycarbonate is much softer than other windshield materials, and, uncoated, has little abrasion resistance. Currently the majority of motorcycles in use have Impact Modified Acrylic. It was the industry standard for many years because it is chemically resistant, more brittle than polycarbonate, more transparent than glass, and is easily formed at high temperatures.

Motorcycle windshield technology is constantly improving. In 2004, GE developed a hard-coated polycarbonate, Lexan Margard, which is now the original equipment manufacturer (OEM) standard material for motorcycle windshields. Lexan Margard provides scratch resistance greater than any other transparent plastic.

Scratching

It is unclear if the use of a windshield wiper will scratch modern motorcycle windshields. Boat windshields, similar to motorcycles, are often made of acrylic or polycarbonate, but are not hard-coated. Many boat owners who have installed an electric wiper on their plastic (acrylic or polycarbonate) windshield have reported scratching as a result. A hard-coated polycarbonate like GE's Lexan Margard, may be hard enough that scratching will not result from windshield wiper use. GE claims that Lexan Margard is thirty times more scratch resistant than untreated acrylic and sixty times more than untreated polycarbonate.

In the future, cyclic testing of the alpha prototype will be necessary to determine if scratching will be an issue.

IV. Alpha Prototype

Brainstorming

From an engineering standpoint, the notion of putting a motorized wiper on a motorcycle presents many potential difficulties. Although windshield wipers exist on automobiles, the technology used does not translate well to a motorcycle. On an automobile, the wiper system occupies far more space than is available on a motorcycle. The wiper motor and electronics are contained under the hood making waterproofing an easier issue to resolve. Automobiles also have much larger engines than motorcycles and can afford to have large powerful wiper motors. Finding a method and position of attachment for a motorcycle is a difficult obstacle. The attachment method must allow the unit work on an array of windshield sizes and shapes; it is also desirable for it to be a simple as possible to avoid ambiguity and misuse. The size and weight of the unit introduced rigid design requirements in order for the wiper to be convenient to store and handle. The first of these questions to be answered was how to eliminate the bulk, weight, and moving parts present in automobile wiper systems. Once answered, motor sizing power considerations, and waterproofing could be addressed.

Oscillatory Motion

In automobiles, the wiper system is no small unit. In order to achieve the oscillatory motion required for wiping, a mechanical system of gear reduction and linkages is used. A short cam is attached to the output of the motor gear reduction. The cam converts the purely rotational motion of the motor into a linearly oscillatory motion of a four bar linkage. The linkage, in turn, converts the linear oscillatory motion to rotational oscillatory motion the wiper blade. This mechanical system is often large, and requires permanent mounting. It is shown in Figure 5. Because of strict size and modularity requirements, this design could not feasibly be adapted for use on a motorcycle.

Figure 5: Typical wiper cam and linkage system

Some automobiles have a rear wiper in which these mechanical components are compacted and contained within the motor housing. It was concluded that even rear wiper motors were to too large and impractical for use on a motorcycle. Figure 6 shows a standard rear wiper motor.

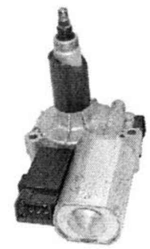


Figure 6: Rear wiper motor

To achieve the desired motion, a combination of limit switches and a simple polarity reversing circuit, was used to switch the polarity of the voltage applied to a small DC gear motor. At either extreme of the wiper's range of motion an internal arm triggers a limit switch and causes the wiper to reverse directions until reaching a switch at the other extreme. Each limit switch acts as a mechanical stop and reverse position for the wiper. This method reduces the number of moving parts and operates very simply. It also provides a means to limit the range of motion of the wiper. For example, the desired motion could be accomplished without switches using an h-bridge and an Arduino microcontroller. In this method, rather than triggering a physical switch, the wiper speed, current, and time spent moving in each direction could be mapped to position of the wiper. Although, this method would accomplish the same task, it would be over-engineered for the problem at hand. Wiping could also be accomplished with the use of one double throw double pole switch (DPDT). Triggering a single switch at opposite ends of the wipe introduces a complex mechanical design. A DPDT switch must remain fully switched in order to keep the connection of power to the motor. In the DPDT switch method tested, there was the possibility of the wiper to be turned off in-between forward and reverse states. In this case, when the wiper did not work when it was turned back on.

This method is likely not robust enough for long-term cyclical use in a wiper. This simple electromechanical method used in the prototype is compact and reliable.

Motor

The heart of the wiper is a Pittman 19.1 volt gear motor. This motor was chosen because it is small and has a large amount of torque (shown in Figure 7). The gears are compactly sealed in the head of the motor.

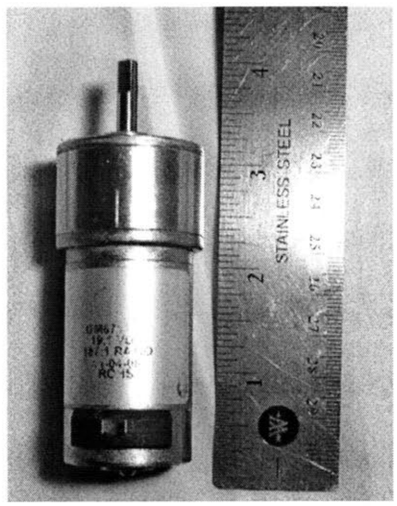


Figure 7: Gear motor used in prototype

Two Pittman gear motors were available for use on the wiper. The table below compares the specifications of each with a standard wiper motor from a small car. Table 3 compares the technical specifications of three different motors.

Table 3: Motor specifications

Data	Units	Value		
		Motor 1 (19.5:1)	**Motor 2 (187:1)**	**Standard**
Reference Voltage	V	12	12	24
Nominal Current	A	0.14	0.14	0.3
No load speed	rpm	250	25	35
Continuous Torque	oz-in	10	62.8	850
Stall Toque	oz-in	45	350	2830
Weight	oz	7	7.3	45

Both motors are considerably less powerful than ones used on automobiles. In future iterations, higher torque motor or higher voltage options will be considered. The 187:1 gear ratio motor was selected for use in the wiper because it offers a considerable amount of torque and, at 12 volts will rotate at a speed comparable to a standard wiper motor.

A few calculations prove that the motor is viable for use on the wiper. A standard wiper motor can supply a continuous torque of 850 oz-in. Estimating that this wiping torque is applied to the motor from a distributed load on a wiper assembly that is about 30" long. This gives us a wiping force of approximately 110 oz to rotate two wipers. The wiper assembly used for the motorcycle is 14" long. In this wiper, the wiping force is applied at a shorter distance from the motor. The wiping force is also lower because it is proportional to the length of the wiping blade. The force required to wipe a motorcycle windshield is estimated to be about 26 oz and is evenly distributed over a 14" wiper arm.

From this, the upper limit on torque required to wipe a motorcycle windshield is calculated to be 182 oz-in. Although the continuous torque of the motor is about half of this value, the 187:1 gear ratio motor is adequate for this iteration of the wiper.

Switches

Rigid lever single pole single throw limit switches were chosen for the wiper. Figure 8 shows the switch used in the prototype. Many other switch possibilities were explored, but snap acting limit switches were the most suited to the use case. Their small size allows for the mechanical portion of the switching apparatus to be very small and compact. The dimensions of each switch are 0.8" x 0.35" x 0.25".

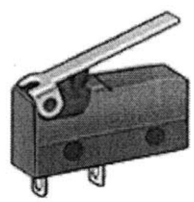


Figure 8: Limit switch used in wiper

Triggering the switches

In the prototype, a CPVC arm extending from the bearing shaft triggers the switches. Rather than a rigid arm protrusion, a compliant arm was chosen so that none of the other components could be damaged in the case of malfunction. For example, if the motor did not reverse directions properly and continued to push against a switch, the CPVC arm would be the first to fail. Figure 9 shows the triggering arm.

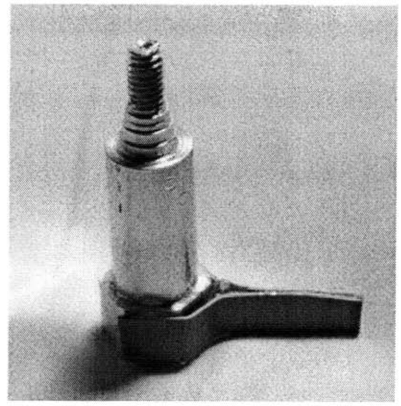


Figure 9: CPVC trigger arm mounted on bearing shaft

Circuitry

An H-bridge combined with a flip-flop and buffer circuit is used to reverse the polarity of the voltage applied to the motor (shown in Figure 10). Each switch provides a control signal to the flip-flop. The flip-flop then sends a constant output to be amplified by the buffer and sent to the h-bridge. The h-bridge takes this output and will change the polarity of the voltage applied to the motor accordingly.

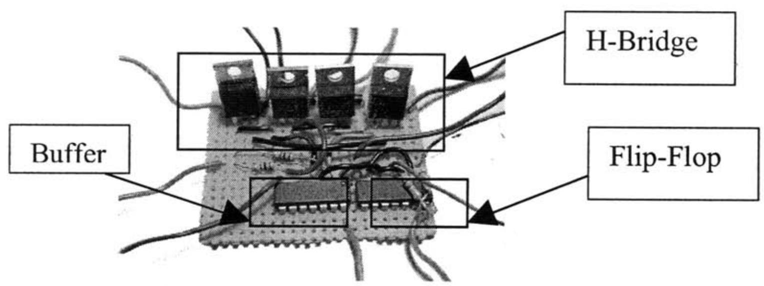


Figure 10: Circuit used in wiper

A flip-flop circuit is ideal for the wiper because it receives a momentary control signal and will maintain one of two outputs in a constant state. The flip-flop used is a SR (Reset-Set) flip-flop and is constructed from a pair of cross-coupled NOR logic gates.

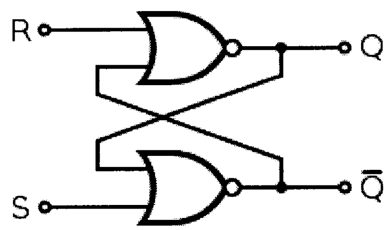


Figure 11: Typical SR flip-flop constructed from two NOR gates

As seen in figure 12, the h-bridge enables a voltage to be applied across the motor in either direction. The two states of the h-bridge are dependent on the signal from the flip-flop. It is constructed with four MOSFET transistors to act as switches and four diodes that resist any back emf from the motor.

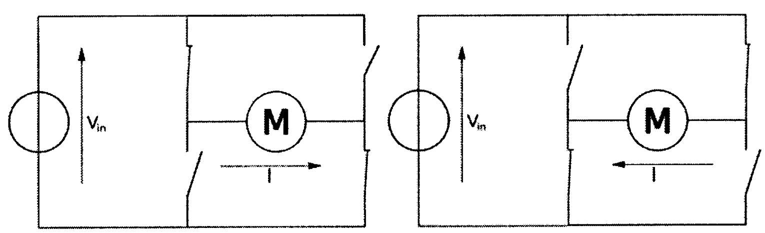


Figure 12: Two basic states of an h-bridge

Attachment

Attachment plays a vital role for this product; two small adjustable locking spring clamps proved to be the most appropriate method for the alpha prototype. Each one has an adjustable clamping width. It is not ideal for the clamp widths to adjust Independently. Once set however, the clamps are easily put into a locked position. A locked clamp is shown in Figure 13.

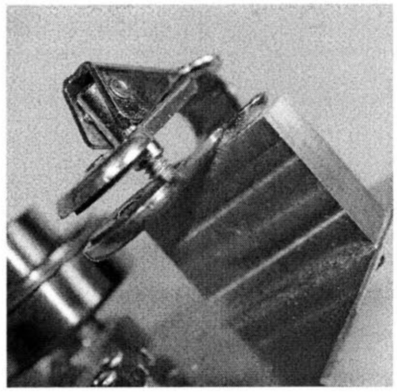


Figure 13: Locking clamp used

In a number of user testing scenarios, it took subjects, on average, less than 7 seconds to attach the unit to a windshield. Another design considered used two solid plates connected by two threaded knobs as a clamping method. This design allowed for a better form factor because it could be designed as part of outer casing. For a final product clamp integration is essential, but for the alpha prototype functionality was the principal concern. The clamps are arranged in line with the motor shaft as seen in Figure 14. Structurally this attempts to minimize the moment on the clamps from the wiper.

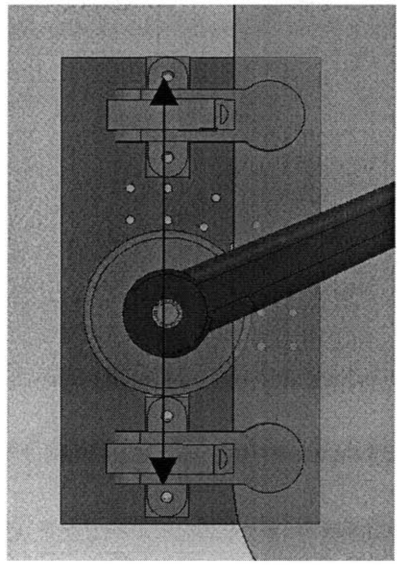


Figure 14: Clamp configuration

In future designs, locking clamps will be integrated with the outer shell of the wiper unit.

Waterproofing

An obvious disadvantage of a motorcycle is keeping things dry when it rains. Waterproofing is especially important for an electromechanical device that to be used exclusively in the rain. A rubber gasket was used to seal the parting line all the way around the thermoformed shell. The gasket yields to fill irregularities in the surface; Because of this, the mating surfaces can be less than perfect. An airtight double-sealed bearing is used to seal the rotating shaft from the motor. The bearing used in the prototype was oversized for the application, but worked fine for an alpha prototype. Cyclical testing is required to observe whether the bearing seal will deteriorate over time.

Wiper

Front automobile windshield wipers are oversized for use on a motorcycle. Rear automobile wipers, however, come in sizes close to ideal for a motorcycle. The wiper used in the prototype is a 15” wiper with a 12” blade. Figure 15 shows the wiper used in the prototype.

Figure 15: Wiper arm used in assembly

The size and orientation of the wiper seems to be ideal. The angle of rotation is currently 45 degrees. The figure below simulates the geometry of the wiping motion on an 18” x 21” windshield. Figure 16 shows the geometry of wiping.

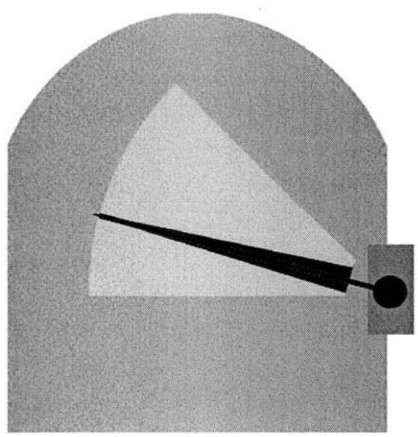


Figure 16: Geometry of wiping

Skeleton

All parts of the assembly are connected rigidly to a 3" x 5.5" alignment plate. This plate acts as a mount for the motor and for the switching to occur. The clips are connected to the plate via spacers. Manufacturing of the plate requires only drilling of through holes. Figure 17 shows the alignment plate.

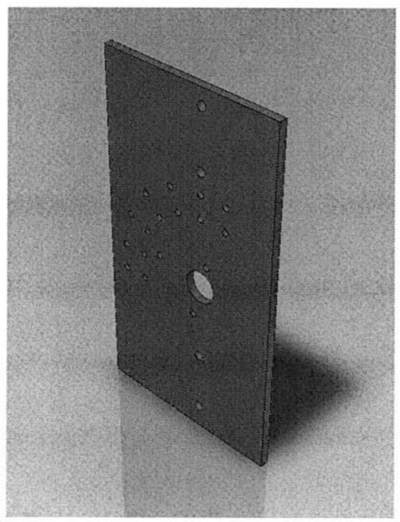


Figure 17: Alignment plate

There are sets of holes at a radius from the motor shaft, to allow for switch positions. This feature was added so that different ranges of motion could be tested.

Power

The unit is powered via the cigarette power outlet that is present on many touring motorcycles. Wiring the device directly to the battery was considered. This would allow for the wiper to be used regardless of whether there was a cigarette power outlet present or was designated to another device. However, from a user interface standpoint, it would add much complexity. Plugging in the device to turn it on has the advantage of being quick and easy.

Shell

The outer shell is thermoformed from 1/16" ABS. ABS is a light thermoplastic. When formed, it provides great structural stability. The molds were made from hard polyurethane foam board. This foam is often used for testing product forms. It is ideal because it can be easily cut and sanded down to a representative form. In this case, each of the forms is cut at the parting line and used as each side of a mold.

Thermoforming is not the ideal process to make a shell for this product. Thermoforming is limits the size, shape, and toughness of forms. It also limits the thickness of the material used. When exploring different forms, molds with hard edges produced webbing on the finished part. Along the same lines, even parts with soft edges far from the parting line often produced webbing. Originally, 1/8" material was to be used but, when attempting to thermoform, it exceeded the molding capabilities of the machine used. Although the 1/16" ABS is structurally rigid, it provides little protection from puncture. Additionally, thermoformed parts are difficult to mate, and require much post processing. In future iterations, an injection-molded shell would be ideal. Injection molding would allow for thicker material, more form possibilities, and make two complementary parts easier to mate. For this iteration, however, thermoforming was appropriate because it allowed for rapid testing of forms. Injection molding requires machining of molds. This is a time intensive process and therefore, not ideal for rapid prototyping. Figure 18 shows an example of a thermoformed part.

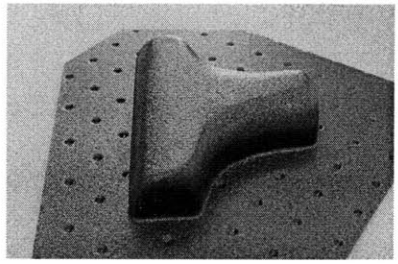
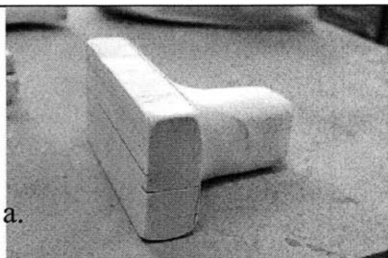
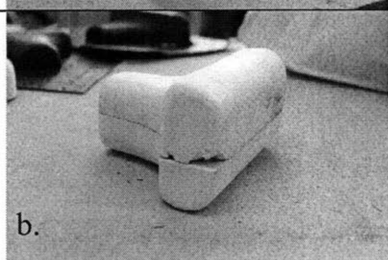


Figure 18: Thermoformed part

Form

Multiple form factors were explored for this iteration of the wiper. Although all had the same overall structure, each form explored different detail possibilities. The internal wiper unit determined the structure of the outer shell. The protrusion made by the motor presented an excellent holding position. From here, each form experimented with different edge transitions. The different forms are presented in Table 4.

Table 4: Form exploration

Form	Type of continuity	Characteristics
 a.	Positional Continuity	Precise, Structured, Dangerous
 b.	Tangent Continuity	Utility, Practical, Unrefined
 c.	Curvature Continuity	Sophisticated, Fluid, Inviting

The curvature continuity used here, is intended to indicate to the user where to hold the unit during attachment or transport. Each form attempts to utilize the three types of transitional continuity in different ways. All of the forms share similar continuity for the handle. The first form (form a) uses hard edges on the front portion to express that this is the structured and precise portion of the wiper unit; since it is near the rotating wiper blade, hard edges are used to make this portion of the unit un-inviting. The third form (form c) applies curvature continuity to a majority of the form. In many products, the user interprets this as calm and refined. For the prototype, the second form (form b) is used because it best conveys the utility of the product and indicates how to use it. This form uses tangential continuity, often called a fillet, in many places. This type of continuity is often seen on practical products used for their utility. This notion best suits the intended user of the wiper.

Full Assembly

The assembled wiper unit is presented in Figures 19-21.

Figure 19: Full wiper assembly

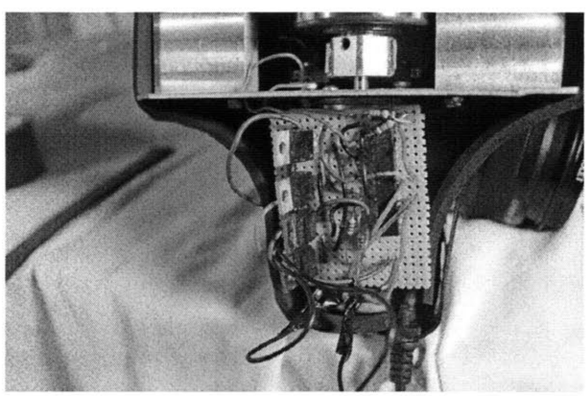


Figure 20: Inside the wiper unit

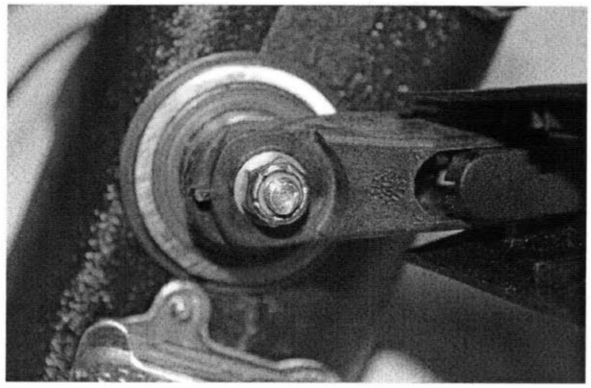


Figure 21: Wiper blade attachment point

As mentioned before, motorcycle testing was unavailable due to the danger of scratching an acrylic windshield. The wiper was tested for twenty minutes during a moderate rain. A mirror was substituted for a windshield and a 12V motorcycle battery for an actual motorcycle. The wiper performance is mostly as expected. The speed of wipe is slower than expected, but sufficient to clear vertical downpour. When testing voltages within the unit, voltage losses in the circuit were discovered. The transistors used dissipate about 2-4 of the 12 volts from the battery lowering the voltage supplied to the motor to about 8-9 volts. One way to address this would be to add a 2:1 transformer to the circuit. This would allow the motor to be run at 20V, making it faster and more powerful. Another solution would be to install a motor with a lower gear ratio. The gasket installed kept rain out completely. The testing performed was insufficient to attain usable data. Use conditions on a motorcycle would invariably be much more severe than those tested. The test is documented in Figures 22 and 23.

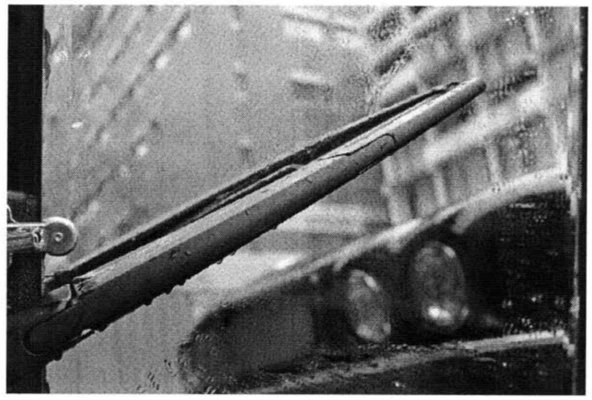


Figure 22: The wiper in action

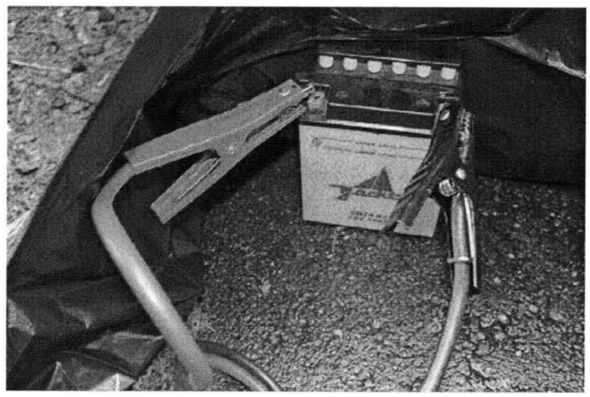


Figure 23: 12V battery used for testing

V. Conclusion

Production of a modular motorcycle windshield wiper has proven itself to be a viable product option. Customer and market research reveals the demand for such a product. The completed alpha prototype serves many purposes. Chiefly, it verifies that a windshield wiper for a motorcycle can be made with the appropriate size, ease of use, and function. The means, by which the oscillatory motion of the wiper is accomplished, optimize mechanical and electrical design. The basic form of the product, although somewhat deterministic, has been realized. It attempts to convey the function and utility of the product. Future work would entail cyclic testing of the wiper unit. It has not been established whether the wiper would scratch hard-coated motorcycle windshields; testing on a Lexan Margard motorcycle windshield would yield the most definitive answer. Also cyclic testing in severe rain would establish the wiper enclosure's ability to stay waterproof. In future iterations of the wiper, material selection for and method of production of the external shell must be reevaluated. Thermoforming is likely not the best process to make the shell. Injection molding is suspected to be the optimal alternative.

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